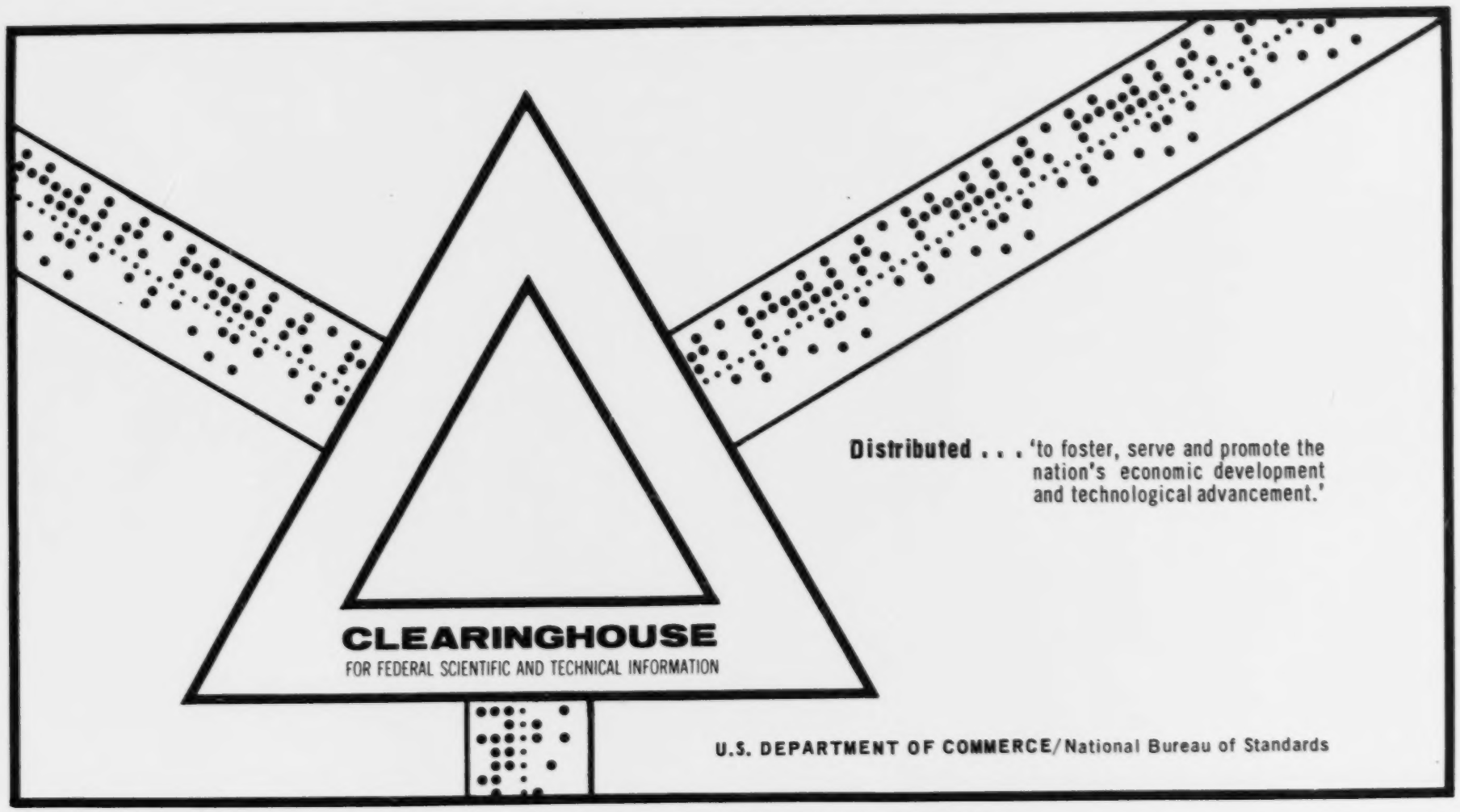
PB 187 392

ATMOSPHERIC OZONE MEASUREMENTS

I. G. Burough

Dalmo Victor Company
Belmont, California

12 December 1967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PB187392

FINAL REPORT
for
ATMOSPHERIC OZONE MEASUREMENTS

Prepared for

Public Health Service

Robert Taft Sanitary Engineering Center

Cincinatti, Ohio

PH 86-69-55

DALMO VICTOR

BELMONT, CALIFORNIA

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DALMO VICTOR COMPANY
BELMONT, CALIFORNIA • LY 1-1414

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I. INTRODUCTION

This is the final report to be issued under Contract No. PH 86-68-55, Atmospheric Ozone Measurements. It includes data submitted in progress reports of November 21, 1967 and November 28, 1967, in addition to data that was reduced following the second progress report.

The scope of this contract was to perform long path infrared absorption measurements of atmospheric ozone concentrations in Los Angeles, California, using the Dalmo Victor Ozone Sensor.

The sensor used for these studies is a modified LOPAIR system, which is a military chemical warfare agent detector that is currently in production at Dalmo Victor.

Tabulated data and tables of simple correlation coefficients are included to provide a comparison with existing ozone sensors.

II. SYSTEM DESCRIPTION

The Dalmo Victor Ozone Sensor measures ozone concentrations continuously as a function of time. It consists of a transmitter and a receiver which are separated by a line-of-sight path of 800 feet to 1600 feet.

The infrared source for the transmitter is a Nernst glower. The energy from the Nernst glower is collimated by a 24 inch f/1 parabolic mirror. A filter-chopper is used to modulate the infrared source by sequentially blocking the radiation. Two bands of energy are alternately transmitted; a band of energy centered at the ozone absorption wavelength of 9.6 microns, the so called "analytical band," (A) and a "reference band," consisting of two bands on each side of the analytical band. See Figures II-2, II-3, and II-4 for spectra data.

The energy of the (R) band is set equal to that of the (A) band in the absence of ozone. As absorption of atmospheric ozone takes place, the (A) band is partially attenuated, while the (R) band remains constant. The receiver consists of a 24 inch f/1 parabolic mirror and a thermistor bolometer. In the absence of ozone the signal impinging of the thermistor bolometer is constant, since (A) and (R) are equal. However, when ozone is in the path of the infrared beam of energy, the absorption of ozone in the (A) band causes an unbalance in the energy between (A) and (R). Electronic signal processing measures this difference which is then read out on a recorder in PPM of ozone after appropriate calibration.

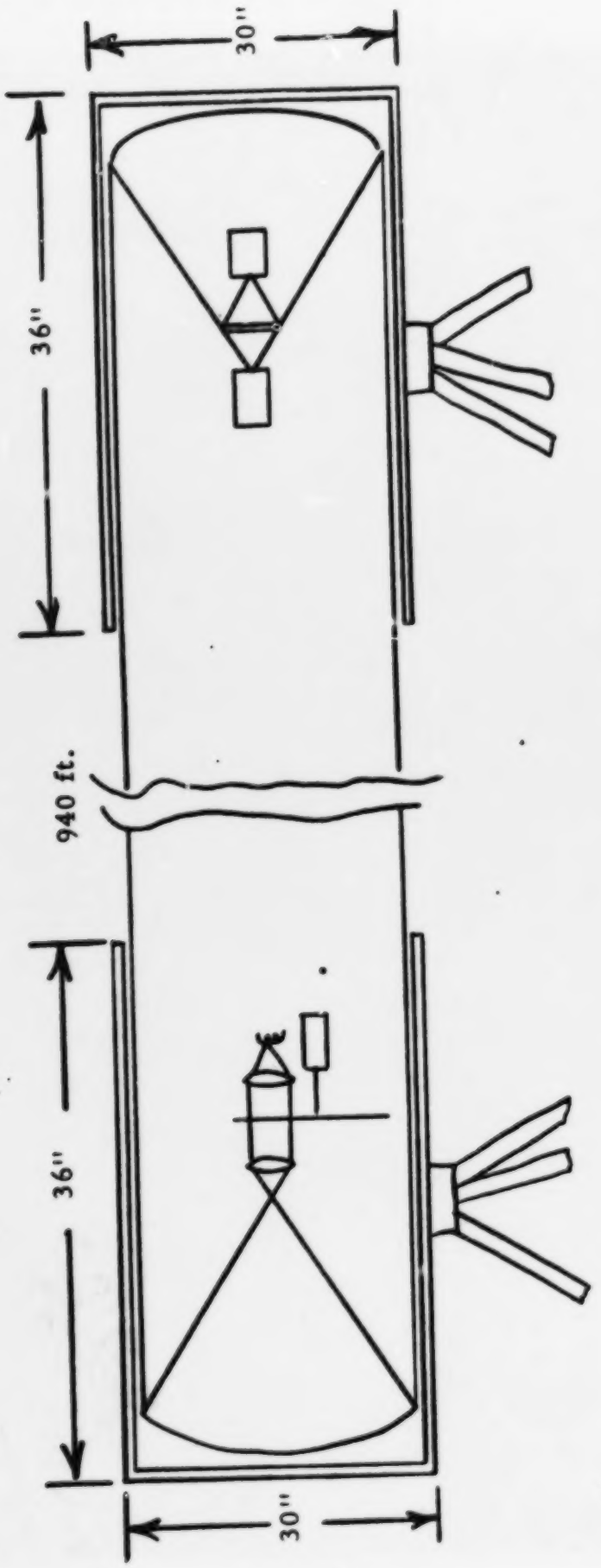


Figure II-1 General Optical Layout

PH86-68-55

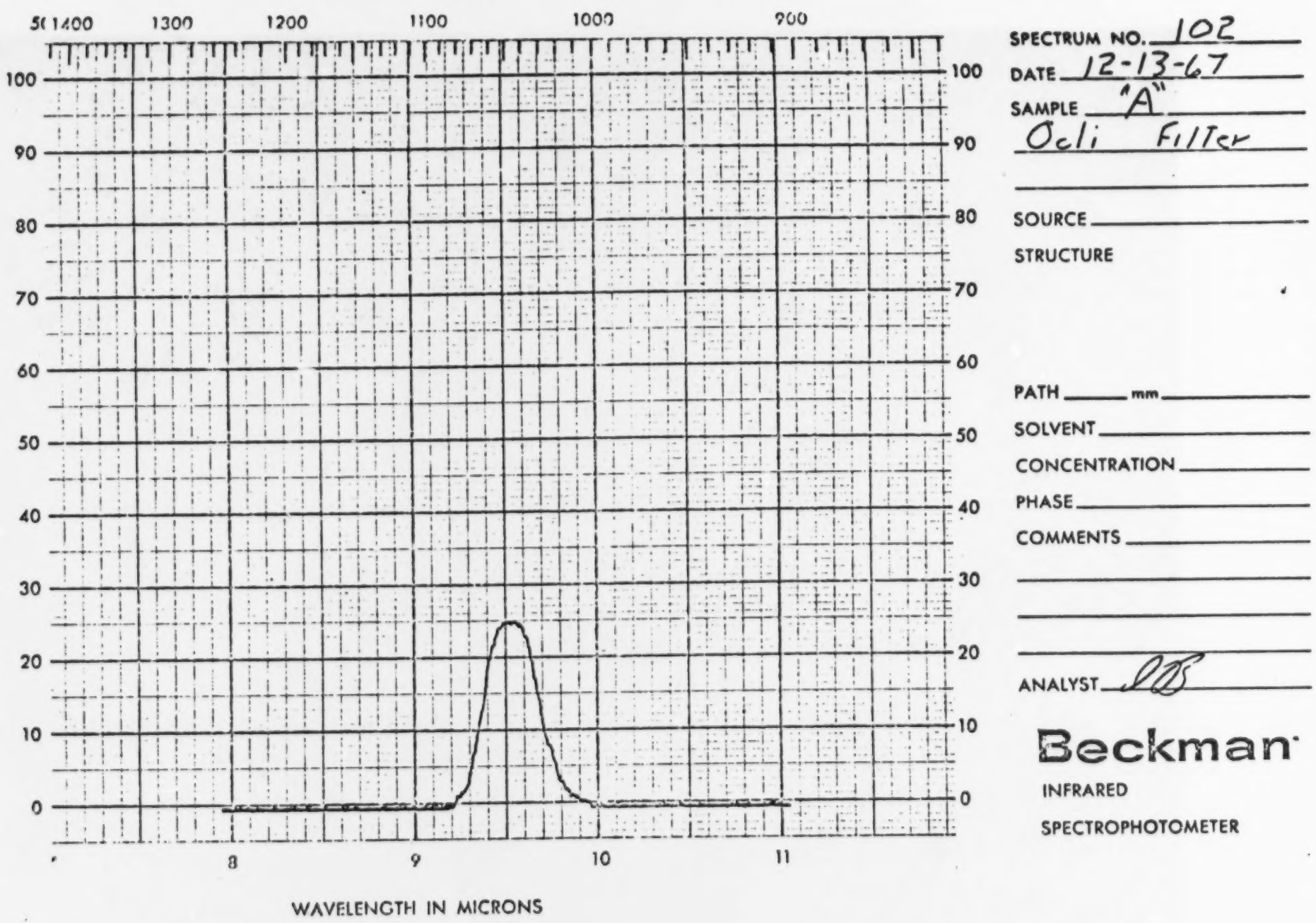
WHEN REORDERING SPECIFY CHART NO. 18920 BECKMAN INSTRUMENTS, INC., FULLERTON, CALIFORNIA, U.S.A.

SPECTRUM NO. 101
DATE 12-13-67
SAMPLE Ocli
Bolometer window
SOURCE
STRUCTURE
PATH ____ mm
SOLVENT
CONCENTRATION
PHASE
COMMENTS
ANALYST JB

Beckman
INFRARED
SPECTROPHOTOMETER

PH 86-68-55

Figure II-2 Thermistor Bolometer Window Spectra



SPECTRUM NO. 102
DATE 12-13-67
SAMPLE "A"
Ocli Filter

SOURCE

STRUCTURE

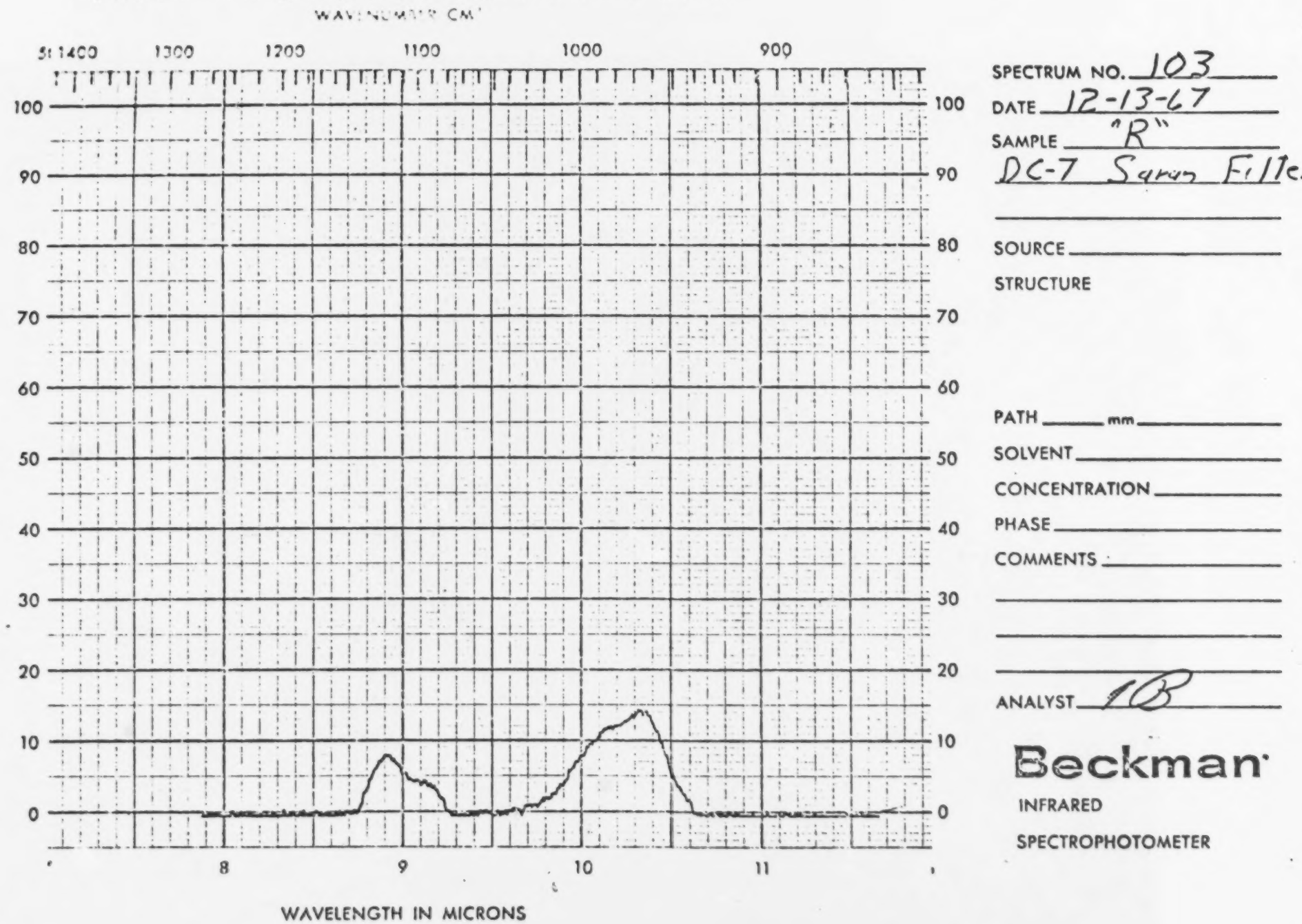
PATH ____ mm
SOLVENT
CONCENTRATION
PHASE
COMMENTS

ANALYST

Beckman
INFRARED
SPECTROPHOTOMETER

PH 86-68-55

Figure II-3 "A" Filter Spectra



SPECTRUM NO. 103
DATE 12-13-67
SAMPLE "R"
DC-7 Saran Filter

SOURCE
STRUCTURE

PATH ____ mm
SOLVENT
CONCENTRATION
PHASE
COMMENTS

ANALYST

Beckman
INFRARED
SPECTROPHOTOMETER

Figure II-4 "R" Filter Spectra

PH 86-68-55

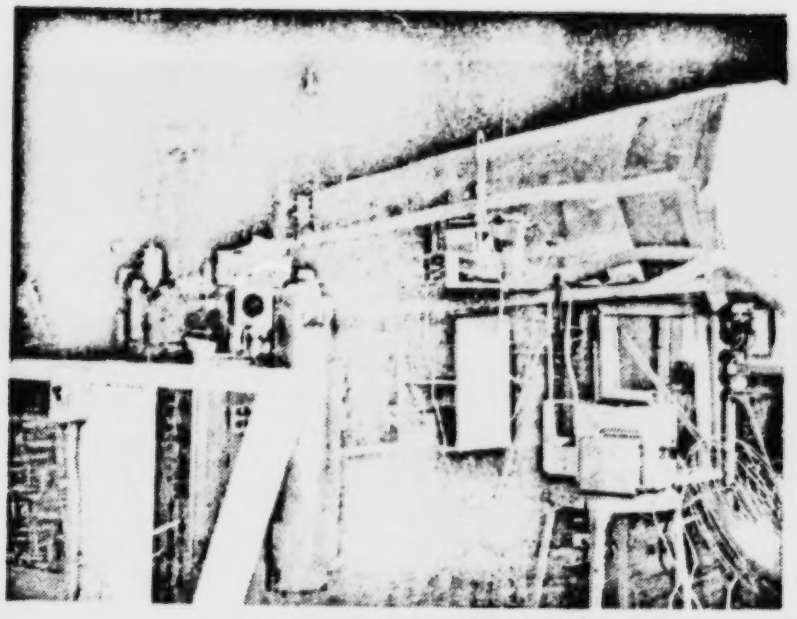
III. CALIBRATION

Since the Dalmo Victor Ozone Sensor measures ozone in terms of its optical absorption, it is necessary to provide a concentration, path length, calibration factor. The calibration control provides this factor by scaling the sensor output for varying path lengths. See Figure III-2 for a graph of the calibration adjustment required for path lengths between 800 and 1400 feet.

The calibration of the Dalmo Victor Ozone Sensor is accomplished by the introduction into the optical path of a test cell of accurately known length. The test cell is filled with ozone generated by passing oxygen through a high voltage electric discharge apparatus. The quantity of ozone in the cell is determined chemically. See Appendix A for the chemical test procedure. The concentration of ozone in the test cell is increased by the ratio of the nominal operational path length to the test cell length.

The upper limits of calibration occurred when large quantities of ozone cause non-linearities. This is best illustrated in Mc Caa*, an excellent paper on the infrared absorption bands of ozone. His curves, shown in Figures 14 through 16, all show the usual linear proportions of integrated band absorption for small quantities of gas.

*David J. McCaa, et al., Ohio State Univ. Feb. 67 AD 653 195



Test Cell

TEST CELL

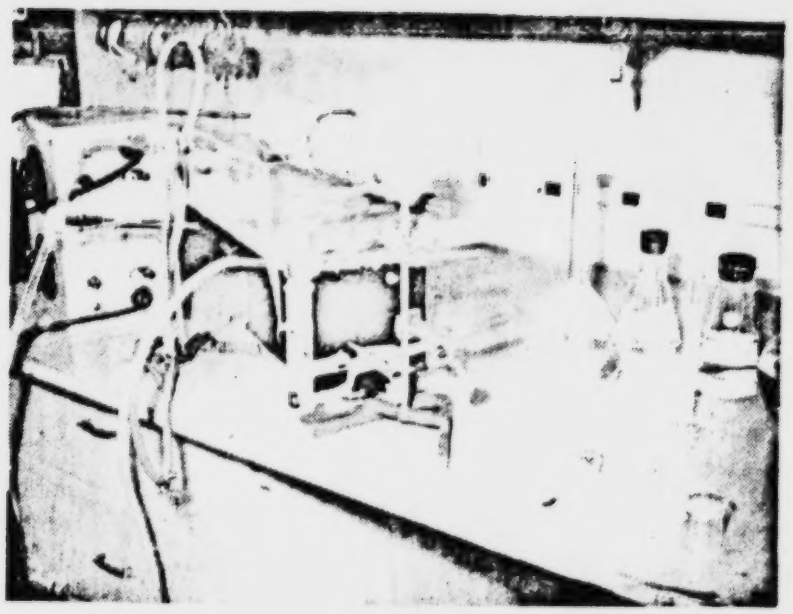


Figure III - 1 Ozone Generator

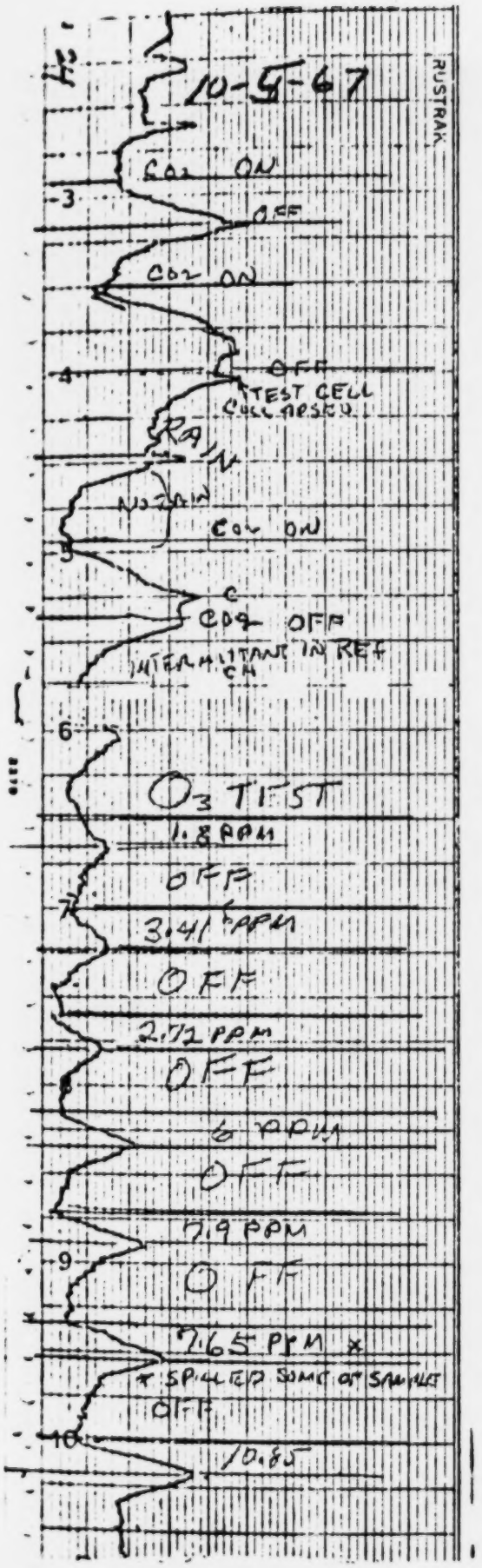
NOT REPRODUCIBLE

NOT REPRODUCIBLE

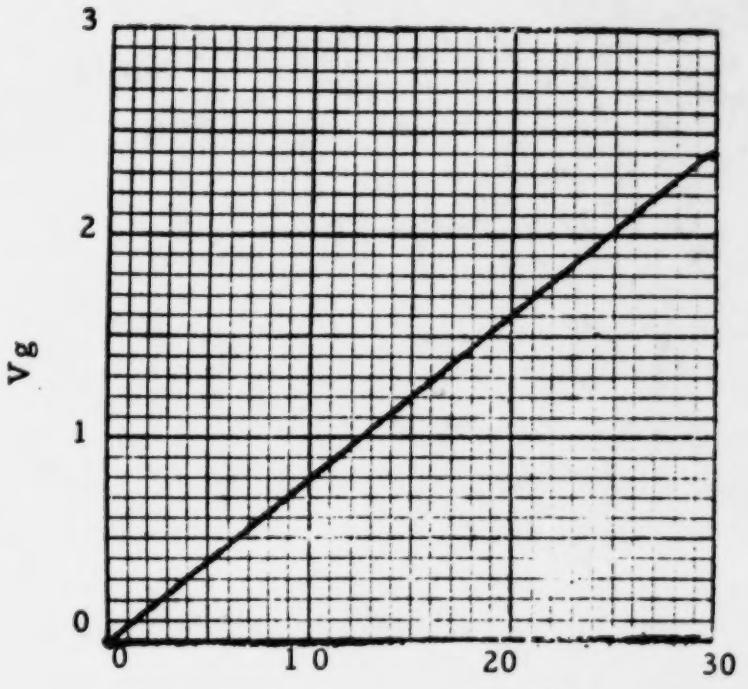
Since the Dalmo Victor Ozone Sensor has a finite bandwidth the D/V curves for large concentration will differ in detail when the band absorption exceeds about 30% absorption. As that value is never approached, a linear relationship is always present, as is illustrated with the calibration curves on Page 8.

Calibration is then:

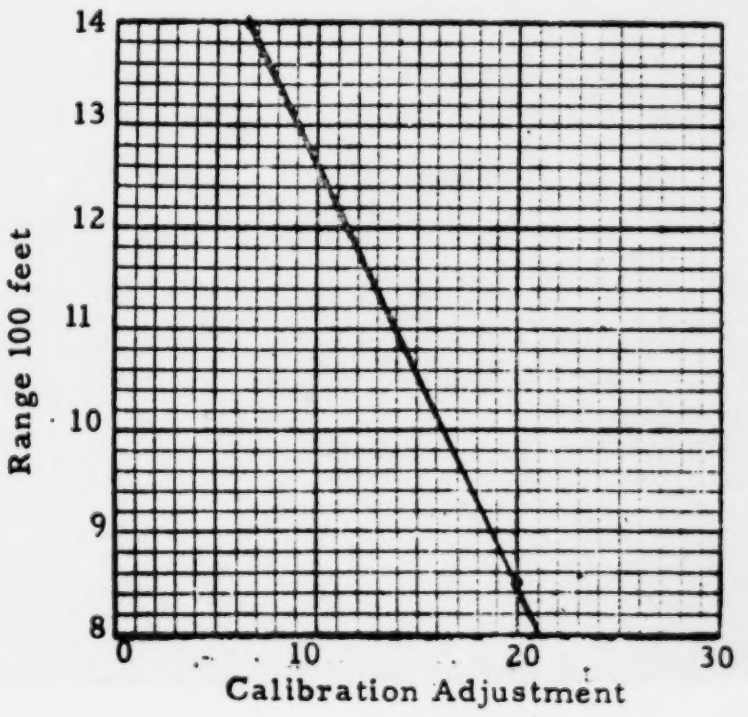
1. Dependent on a full scale point taken with the same number of ozone molecules as in the full path but all concentrated at one end of the path in a test cell.
2. Only a scale factor which may be changed for different path lengths.
3. Linear by virtue of the small quantities of maximum absorption.



Calibration Test Data



Calibration Adjustment



Calibration Adjustment

Figure III-2

PH 86-68-55

IV. MEASUREMENTS

A site of operation was selected in the downtown area of Los Angeles. Operating site for the transmitter was the seventh floor of the Los Angeles Air Pollution Control District building at 434 S. San Pedro Street. The receiver was placed 940 feet away on the sixth floor of the Sixth and San Pedro building. Elevation of the receiver site was 68 feet and that of the transmitter 84 feet. The instrument was placed in operation on November 7, 1967. Data gathering began on November 9 and continued through November 22, 1967.

Data was also gathered from three other ozone sensors over a portion of this period. The sources of data and their locations are: Mast Ozone Recorder at the receiver site; Beckman Total Oxidant Recorder, operated by the Los Angeles Air Pollution Control District, at 434 S. San Pedro Street; and Regener device, operated by Research Triangle Institute personnel at the Air Pollution Control District building. The Beckman and Regener instruments were on the sixth floor at approximately 68 feet above street level. See Figure IV - 1 for photographs of the transmitter and receiver sites.

See Figure IV-2 for photographs of the transmitter and receiver units in operation.

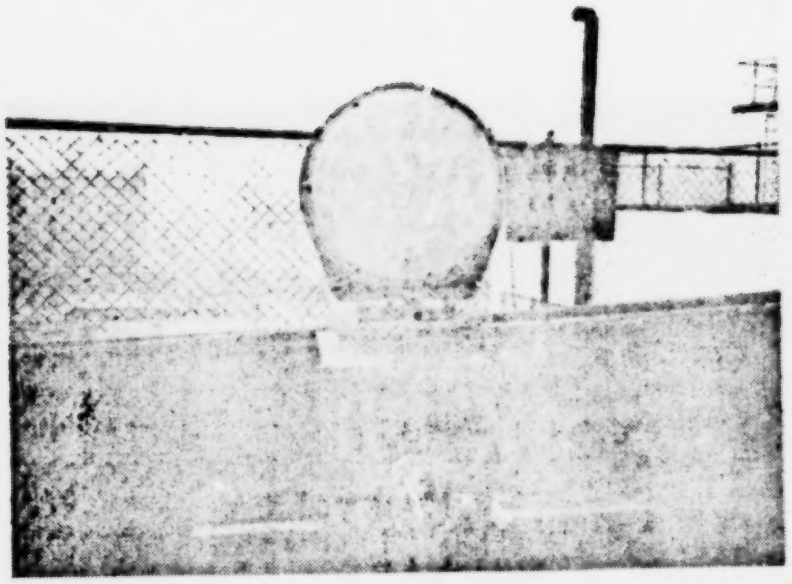
Data reduction consisted of tabulating data from strip chart recorders, and computing simple correlation coefficients. In the case of the Dalmo Victor IR and Dalmo Victor Mast, the values are "eye ball" averages centered at the time interval indicated. The Beckman and Regener instruments readings are peak values taken at the time indicated.

NOT REPRODUCIBLE

TRANSMITTER SITE

NOT REPRODUCIBLE

Figure IV-1 Receiver Site



Transmitter Installed at Field Site •

NOT REPRODUCIBLE

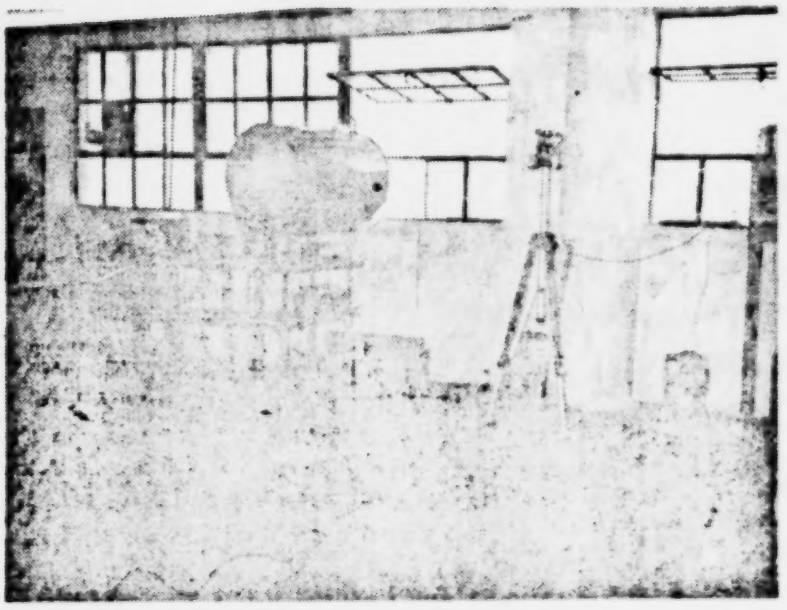


Figure IV-2 Receiver Installed at Field Site

NOT REPRODUCIBLE

V. RESULTS

The correlation between the Dalmo Victor Ozone Sensor and the other instruments was calculated in the following manner

$$R_{AB} = \frac{\sum A_i \quad \sum B_i}{\sqrt{\left(\sum A_i\right)^2\left(\sum B_i\right)^2}}$$

Where R = correlation coefficient

A_i = normalized values of ozone level for the Dalmo Victor Ozone Sensor

B_i = normalized values of ozone level for the other instruments.

A_i and B_i were normalized by making their average value equal to zero:

$$\bar{A}_i = \sum_{i=1}^{n} A_i = 0$$

Twenty minute intervals were used over the period of 0800 hours to 2040 hours for each of the following days.

November 9, 1967

	D/V IR	D/V Mast	Regener	L.A.County
D/V I.R. Sensor	1.0			
D/V Mast	.86	1.0		
Regener	.65	.71	1.0	
L.A. County	.86	.91	.62	1.0

November 10, 1967

	D/V IR	D/V Mast	Regener	L.A.County
D/V I.R. Sensor	1.0			
D/V Mast	.82	1.0		
Regener	.81	.91	1.0	
L.A. County	.88	.95	.91	1.0

November 11, 1967

D/V I.R. Sensor	1.0			
D/V Mast	.79	1.0		
Regener	.76	.98	1.0	
L.A. County	.80	.98	.96	1.0
	D/V IR	D/V Mast	Regener	L.A. County

November 13, 1967

D/V I.R. Sensor	1.0			
D/V Mast	.75	1.0		
Regener	.66	.75	1.0	
L.A.County	.64	.94	.78	1.0
	D/V IR	D/V Mast	Regener	L.A. County

November 14, 1967

D/V I.R. Sensor	1.0			
D/V Mast	.60	1.0		
Regener	.49	.93	1.0	
L.A.County	.49	.96	.95	1.0
	D/V IR	D/V Mast	Regener	L. A. County

November 15, 1967

D/V I.R. Sensor	1.0			
D/V Mast	.78	1.0		
Regener	.85	.94	1.0	
L.A.County	.79	.92	.93	1.0
	D/V IR	D/V Mast	Regener	L.A.County

In reviewing the tables of correlation coefficients, it is noted that the highest correlation found is between Los Angeles County and D/V Mast. This is as expected since they are both total oxidant sensors. Although the mast is a coulemetric system and the Beckman a colorimetric, only small differences were noted betwen the two records. The Regener instrument, a chemical luminescence device, also displayed a high correlation to the L. A. County instrument.

The correlation coefficient between D/V I.R. and the three other systems was consistently the lowest tabulated. The lower correlation is the result of two factors. The first is that the D/V I.R. sensor is specific to ozone as opposed to total oxidants. Qualitative tests have indicated that the D/V I.R. sensor is insensitive to atmospheric quantities of SO_2 or NO_2. Second, it provides an averaged value by measuring over a long sample path, as opposed to the other three instruments which are point samplers.

APPENDIX A

CALIBRATION PROCEDURE

The ozone concentration in the test cell was determined by a procedure taken from ASTM Designation D1609-60, Oxidant Concentration of the Atmosphere.

The specific procedure as used at Dalmo Victor follows.

Theory

Ozone will oxidize iodide in solution (I^-) to form iodine (I_2). The amount of iodine formed is proportional to the amount of ozone introduced into the iodide solution. This reaction takes place in acidic or slightly basic solutions; a pH above 8.0 retards or stops the reaction.

The amount of iodine formed can be readily determined by studying the ultraviolet absorption of the solution; a calibration of absorption versus amount of I_2 can be obtained using a spectrophotometer. Since this method measures the amount of iodide oxidized, it does not specifically detect ozone. Most other reductants can be eliminated by boiling the absorbant with hydrogen perioxide, which acts as a powerful oxidizing agent in alkaline solutions; this reaction is catalyzed by the iodide in the absorbant. Hydrogen peroxide itself is readily decomposed by boiling in alkaline solution; again, iodide speeds the reaction. The remaining sample should contain ozone as the only major oxidant. After acidifying the solution, the reaction of ozone with iodide rapidly goes to completion. The iodine is stable and its concentration can be measured spectrophotometrically, using the .352 micron absorption peak.

Reagents

a) KI solution (10 grams per liter) - in 500 ml. distilled water dissolve 5.0 grams (triple-beam balance) potassium iodide (KI). Keep stoppered and use fresh - the iodide oxidizes to iodine within a few days in non-alkaline solutions when exposed to air.

b) Sodium Hydroxide Solution (4 grams per liter (- dissolve 4 grams of NaOH in distilled water and dilute to 1 liter.

c) Absorbent - Prepare a 1% ozone absorbant solution by dissolving 10.0 grams potassium iodide (triple beam balance) in 1 liter NaOH solution (b - 4 grams per liter).

d) Hydrogen Peroxide (1:29) - Mix 1 ml. concentrated hydrogen peroxide (H_2O_2, 30%) with 29 ml. of distilled water. Keep solution fairly fresh; it is easily reduced by small quantities of inorganic impurities.

e) Acetic Acid (1:5) - Mix 20 ml. of glacial acetic acid (CH_3COOH) with 100 ml. of distilled water.

f) Iodine, Standard Solution (0.01 N.) - Place 4 grams potassium iodide (kI) in a weighing bottle, add 1 ml. of water, stopper and weigh to the nearest 0.1 milligram. Add approximately 1.27 grams specially purified (resublimed) dry iodine and reweigh to the nearest 0.1 milligram. Transfer solution quantitatively to a 1 liter flask and make up to the mark with distilled water. Store in a brown, glass-stoppered bottle in a cool, dark place. Iodine is quite volatile, though less so in KI solution.

Calibration

The amount of ozone present is revealed by the quantity of iodide ion converted to iodine. By using known solutions of iodine, a correlation between absorption at .352 micron and the known amount of iodine is obtained. The absorption is directly related to the quantity of iodine present in a sample of given size.

Add 1 ml. iodine solution (f) to 500 ml. Kl solution (a). Place a sample in a Corex cell and obtain an optical density reading. Take readings up to 6 ml. I_2 solution (in 1 ml. increments) in the 500 ml. KI solution, as well as for pure KI solution. Plot a graph of absorption versus micrograms per ml. of iodine (from known concentration of iodine solution); or versus micrograms per ml. of ozone, using the conversion factor: 1 part iodine equals 0.19 parts ozone by weight (from stoichiometry) - see Figure 2 and sample calculations. Any absorption measurement may now be correlated with the amount of iodine, and indirectly with the amount of ozone. Figure 1 shows a typical calibration run with pure KI solution and various concentrations of I_2 in KI solution.

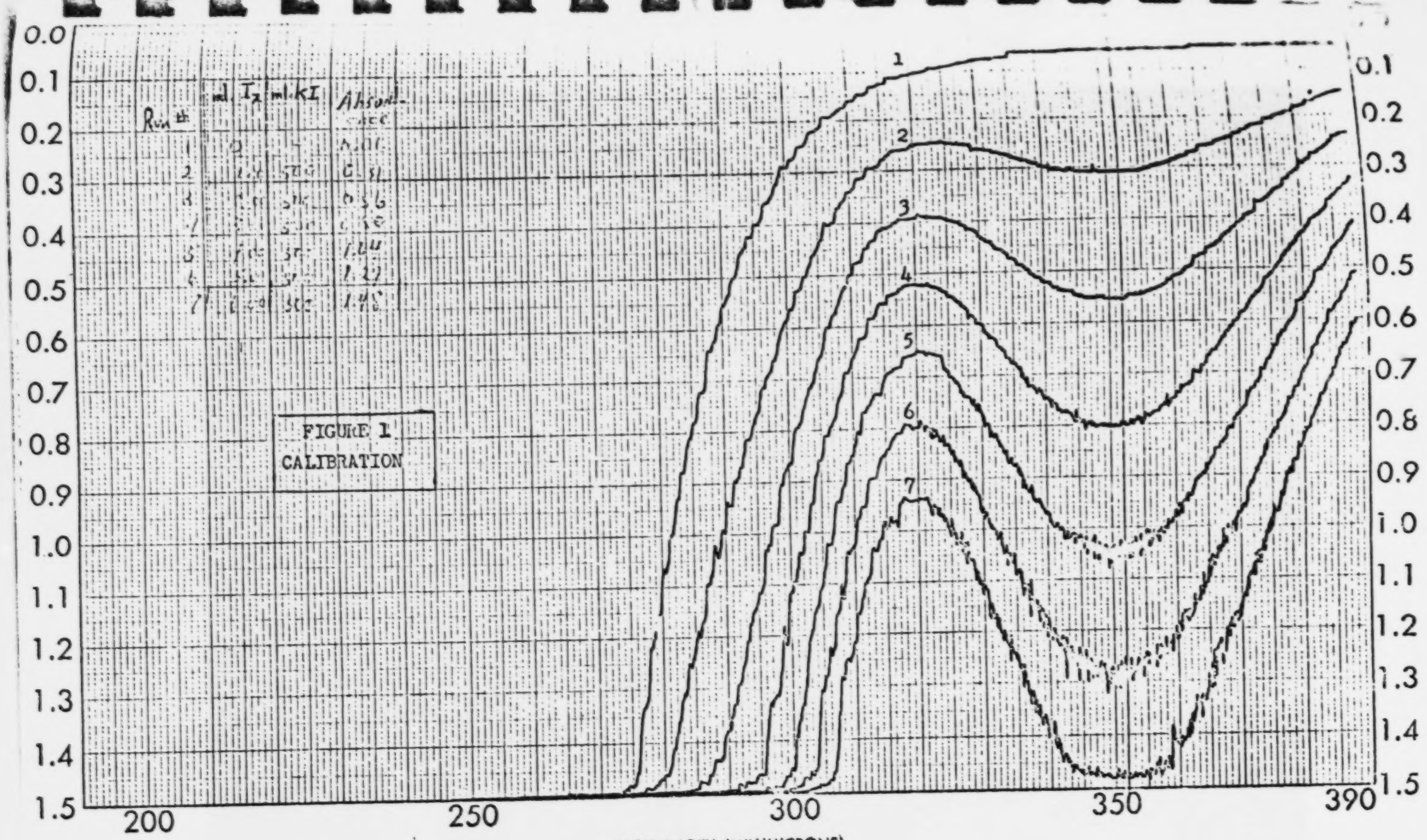
Test Method

Bubble the air to be tested through a sample (e.g., 25 ml.) of absorbent solution (C), using a midget impinger. The flow rate should be about 500 ml./min. and should be monitored with a flowmeter.

Take a sampling time of from 5 to 20 minutes, and vary this to obtain an absorption reading on the spectrophotometer between 0.4 and 1.4.

After completing the bubbling, add to the solution two drops of dilute H_2O_2 (d) and bring to a boil. Cool by placing solution beaker in a bath of water. Add sufficient acetic acid (e) to adjust the pH to 3.8. Distilled water may be added to bring the volume up to some standard volume (25 ml. in sample calculations), or the volume may simply be noted for further calculations. Allow 2 minutes for the reaction to go to completion.

Rinse a clean Corex cell with the solution, then pour solution into cell and measure absorbance at .352 micron. Correlate this reading with the quantity of ozone in the sample, using Figure 2; see section on "sample calculations" for further determination of concentration of ozone in the air sample.



PH86-68-55

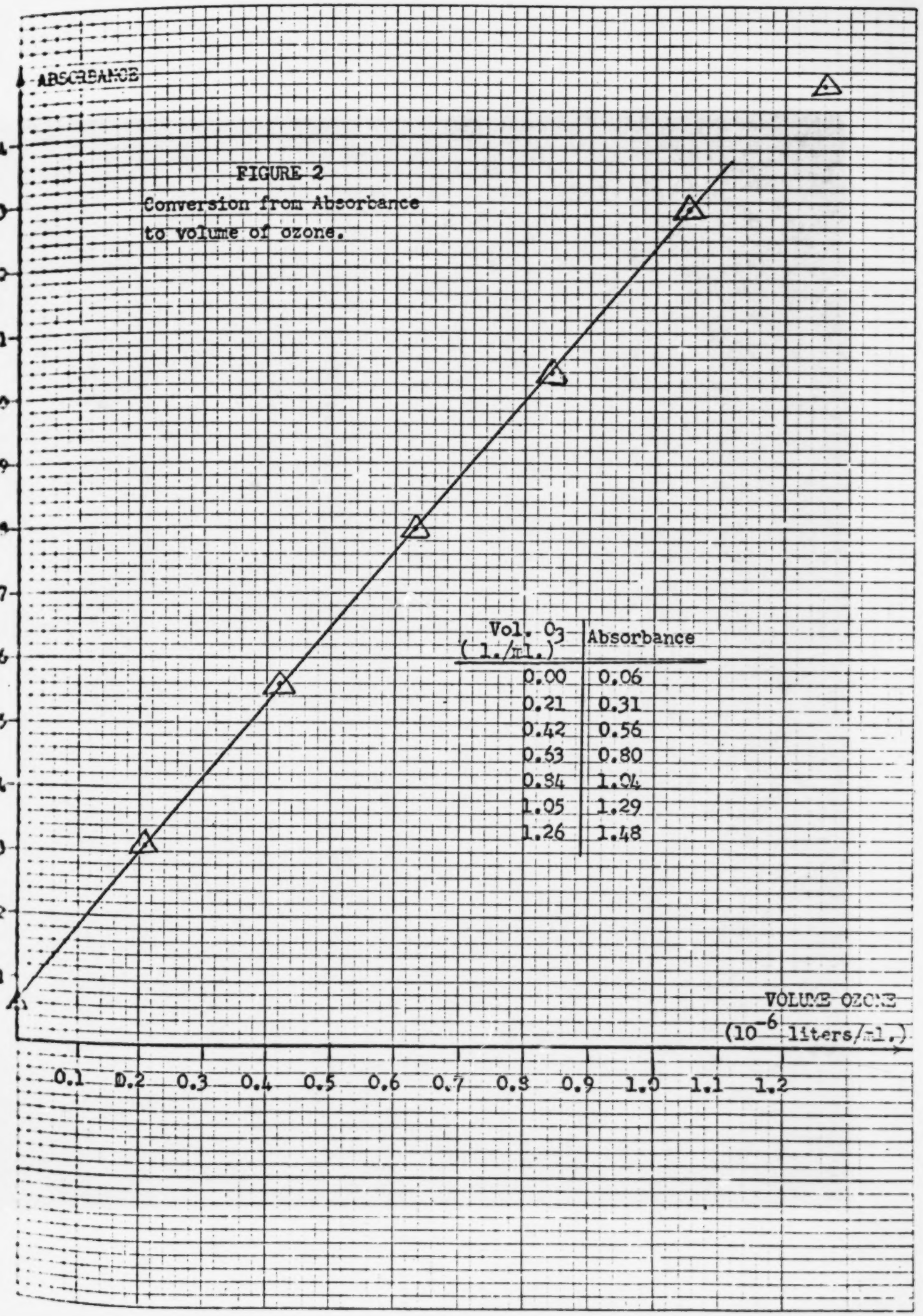
SAMPLE I_2 in KI soln.	CURVE NO. Calibration Curves	SCAN SPEED Slow	OPERATOR [illegible]
	CONC.	SLIT 25	DATE [illegible]
ORIGIN	CELL PATH	REMARKS [illegible]	
SOLVENT	REFERENCE		

PART NO. 202-1511

PERKIN ELMER

FIGURE 2

Conversion from Absorbance to volume of ozone.



Vol. O_3 (1./ml.)	Absorbance
0.00	0.06
0.21	0.31
0.42	0.56
0.63	0.80
0.84	1.04
1.05	1.29
1.26	1.48

SAMPLE CALCULATIONS

A. Calibration

Data (typical)

1.	Weight I_2	1.184 grams
2.	Molecular weight I_2	127 grams
3.	Conversion	1 (I_2): 0.19 (O_3) by weight
4.	Molecular weight O_3	48 grams
5.	Volume of a mole of gas	22.4 liters

a. No. moles of I_2 $\frac{1.184 \text{ grams}}{127 \text{ grams/mole}} = 0.00934$ moles

in 1 liter: 0.00934 N. solution

b. Concentration: $\frac{1.184 \text{ grams}}{1 \text{ liter}} = 1.184 \times 10^{-3}$ frams/ml. of I_2

c. Dilutions:

1. 1 ml. I_2 solution
2. 1 ml. I_2 solution in 500 ml. KI solution

$(\frac{1}{500 \text{ ml.}})$ (1 ml.) $(1.184 \times 10^{-3}$ gms/ml.) = 2.34 ml. of I_2.

micrograms/absorbance = 0.31

3. 6 ml. I_2 solution in 500 ml. KI solution

$(\frac{1}{500 \text{ ml.}})$ (6 ml.) $(1.184 \times 10^{-3}$ grams/ml.) =

14.21 grams/absorbance = 1.48

SAMPLE CALCULATIONS
(Continued)

d. Conversion to O_3:

(7) (14.21 gms/ml. I_2) (0.19 O_3/I_2) = 2.70 μgms/ml. of O_3

e. Conversion to volume:

(7) (2.70 gms/ml. of O_3)$(\frac{22.4 \text{ liters}}{48 \times 10^6 \ \mu\text{gms.}})$ =

1.260×10^{-6} liters of O_3 per ml. of solution.

(If one liter of air was used, this would give 1.26 ppm per ml. of the O_3 solution used; if two liters, then 0.63 ppm per ml.; etc.)

EQUIPMENT:

Perkin-Elmer #202 Ultraviolet - Visible Spectrophotometer

Beckman Model H2 Glass Electrode pH Meter

REFERENCES:

Smith, R.G., and Diamond, P., "The Microdetermination of Ozone (Preliminary Studies)," American Industrial Hygiene Association Quarterly, Vol. 13, pp. 235-238 (1952).

ASTM Designation: D 1609-60, "Standard Method of Test for Oxidant (Ozone) Content of the Atmosphere," ASTM Standards.

ACS Monograph #21 (Mar. 1959), Ozone Chemistry and Technology, (various articles).

APPENDIX B

Tabulated Data

DALMO VICTOR OZONE SENSOR

DATA REDUCTION

November 9, 1967

All Readings in PPB

SYSTEM			
D/V I.R.	D/V Mast	Regener	L.A. County
10	10	0	14
20	25	0	26
25	25	0	36
30	30	0	42
30	30	1	44
40	40	10	64
45	40	17	70
58	40	8	88
59	55	15	110
58	65	55	112
86	155	55	134
115	150	55	182
92	190	78	176
59	140	110	124
86	160	93	130
49	160	98	162
115	140	96	132
81	105	130	100
75	70	130	74
69	60	80	50
63	70	39	48
69	90	44	56
86	70	63	96
80	90	57	96
63	100	91	76
52	60	73	56
29	40	67	38
23	15	76	20
12	15	27	20
23	15	0	20
35	15	3	20
52	15	11	20
23	15	1	20
46	20	0	20
63	40	0	20
29	30	1	20

D/V Ozone Sensor Data Reduction
All readings in PPB

November 9, 1967
Page Two

TIME	D/V I.R.	D/V Mast	Regener	L.A. County
2000	35	30	24	20
2020	29	45	0	20
2040	35	35	22	20
2100	29	30	32	20
2120	29	25	5	20
2140	29	20	1	20
2200	23	25	0	20
2220	17	20	0	20
2240	23	20	0	20
2300	35	20	0	20
2320	23	20	0	20
2340	12	10	0	20
2400	12	10	0	15
2420	184	10	15	15
2440	46	10	15	15
0100	17	10	15	15
0120	35	10	15	15
0140	40	10	15	15
0200	35	10	15	15
0220	46	15	15	15
0240	17	15	15	15
0300	6	20	15	15
0320	6	25	15	15
0340	12	25	15	15
0400	17	15	15	15
0420	23	15	0	15
0440	29	15	0	15
0500	23	15	0	15
0520		15	15	15
0540		10	15	15
0600		10	15	15
0620		10	15	15
0640		10	15	15
0700		10	15	15
0720		10	15	15
0740		10	15	15
0800		10	15	15

DALMO VICTOR OZONE SENSOR

DATA REDUCTION

November 10, 1967

All Readings in PPB

TIME	D/V I.R.	D/V Mast	Regener	L.A. County
0800	20	10	1.0	40
0820	20	10	1.0	40
0840	28	10	1.0	45
0900	30	10	1.0	50
0920	30	10	1.0	50
0940	40	10	1.0	55
1000	40	10	1.0	60
1020	45	30	9	60
1040	45	45	23	70
1100	46	50	58	70
1120	46	80	81	90
1140	46	65	61	100
1200	46	100	67	130
1220	46	90	130	85
1240	69	110	120	170
1300	69	120	180	160
1320	105	140	150	160
1340	98	170	170	180
1400	126	180	120	210
1420	105	155	100	150
1440	91	160	110	155
1500	46	140	78	145
1520	35	120	90	125
1540	23	110	61	110
1600	12	70	44	55
1620	0	50	6	50
1640	0	20	17	40
1700	0	20	6	60
1720	0	20	0	40
1740	0	20	0	40
1800	0	20	0	25
1820	12	20	0	25
1840	12	20	0	25
1900	0	20	0	25
1920	17	20	0	25
1940	12	20	0	25
2000	17	20	0	30

)/V Ozone Sensor Data Reduction
All Readings in PPB

November 10, 1967
Page Two

TIME	D/V I.R.	D/V Mast	Regener	L. A. County
2020	23	20	0	30
2040	17	20	0	30
2100	17	20	0	30
2140	57	20	0	30
2200	69	20	0	30
2220	75	20	13	30
2240	35	20	31	30
2300	29	20	57	30
2320	17	20	97	30
2340	12	20	126	30
2400	6	20	"	30
2420	6	20	"	30
2440	12	20	"	30
0100	17	20	"	30
0120	12	20	"	30
0140	12	20	"	30
0200	12	20	"	30
0220	12	20	"	25
0240	6	20	No Data	25
0300	6	20	"	25
0320	6	20	"	25
0340	6	20	"	20
0400	6	20	"	20
0420	0	20	"	20
0440	0	20	"	20
0500	0	20	"	10
0520	0	20	"	10
0540	0	20	"	10
0600	0	20	"	10
0620	0	20	"	10
0640	0	20	"	10
0700	0	20	"	10
0720	0	20	"	10
0740	0	20	"	10
0800	)	20	"	10

DALMO VICTOR OZONE SENSOR

DATA REDUCTION

November 11, 1967

	SYSTEM			
TIME	D/V I.R.	D/V Mast	Regener	L.A. County
0800	0	10	6	15
0820	12	20	6	20
0840	12	25	9	20
0900	17	30	8	20
0920	17	30	15	30
0940	29	50	30	40
1000	46	70	33	75
1020	46	90	30	90
1040	63	85	30	80
1100	69	80	45	50
1120	91	100	48	70
1140	86	110	76	70
1200	81	90	63	70
1220	86	85	51	70
1240	81	90	76	80
1300	81	130	109	125
1320	75	140	160	130
1340	91	245	208	180
1400	112	280	200	240
1420	126	255	193	240
1440	126	250	225	220
1500	126	250	181	220
1520	112	210	163	170
1540	120	200	169	180
1600	120	180	160	170
1620	98	170	100	160
1640	112	110	69	80
1700	120	70	48	90
1720	112	30	3	45
1740	75	20	1	40
1800	63	20	0	40
1820	52	20	0	40
1840	46	20	0	40
1900	35	20	0	40
1920	40	20	0	35
1940	35	20	0	35
2000	29	15	0	30

D/V Ozone Sensor Data Reduction
All readings in PPB

November 11, 1967
Page Two

TIME	D/V I.R.	D/V Mast	Regener	L.A. County
2020	29	15	0	30
2040	29	15	0	30
2100	29	15	0	20
2120	35	10	0	15
2140	29	10	0	15
2200	29	10	0	15
2220	23	10	0	30
2240	23	50	0	44
2300	0	60	0	70
2320	0	60	0	80
2340	0	110	0	90
2400	0	105	92	85
2420	0	85	72	85
2440	0	60	66	90
0100	6	105	118	90
0120	12	130	102	130
0140	6	140	118	100
0200	12	140	134	90
0220	17	150	124	120
0240	23	130	98	90
0300		145	138	115
0320		145	108	100
0340		135	122	100
0400		150	118	105
0420		155	105	115
0440		145	102	105
0500		140	92	100
0520		135	98	100
0540		130	85	100
0600		120	72	90
0620		120	72	70
0640		110	69	70
0700		110	55	70
0720		100	58	60
0740		80	51	60
0800		90	58	60

DALMO VICTOR OZONE SENSOR
DATA REDUCTION

November 13, 1967

All Readings in PPB

TIME	D/V I.R.	D/V Mast	Regener	L.A. County
0800		10		10
0820		10		10
0840		10		10
0900		10	4	10
0920		10	8	10
0940		20	4	10
1000		20	2	10
1020		20	40	20
1040		35	56	30
1100		30	84	90
1120		50	99	110
1140		130	139	160
1200	25	150	143	170
1220	10	200	151	180
1240	25	200	174	230
1300	50	210	203	250
1320	85	240	191	210
1340	140	280	238	270
1400	160	270	238	250
1420	150	240	215	240
1440	120	260	116	140
1500	58	140	60	90
1520	60	90	48	60
1540	70	60	32.0	50
1600	50	40	20.0	40
1620	25	30	8	20
1640	30	30	4	25
1700	25	30	20	60
1720	25	40	20	20
1740	30	60	20	100
1800	25	90	48	60
1820	30	40	48	65
1840	40	30	48	20
1900	50	30	48	20
1920	25	30	48	25
1940	30	30	48	15
2000	40	20	20	15

D/V Ozone Sensor Data Reduction
All readings in PPB

November 13, 1967
Page Two

TIME	D/V I.R.	D/V Mast	Regener	L.A.County
2020	30	15		15
2040	35	15		15
2100	30	15		15
2120	25	15		10
2140	40	15		10
2200	45	10		10
2220	50	10	40	10
2240	65	10	20	20
2300	50	10	20	25
2320	55	10	50	25
2340	60	10	No Data	30
2400	60	15	"	Blank Sampling
2420	60	10	"	"
2440	55	10	"	"
0100	60	10	"	"
0120	55	10	"	"
0140	55	10	"	"
0200	60	10	"	"
0220	40	10	"	"
0240	0	10	"	"
0300	0	15	"	"
0320	10	15	"	"
1340	10	15	"	"
0400	10	10	"	"
0420	10	10	"	"
0440	15	10	"	"
0500	15	20	"	"
0520	20	20	"	"
0540	25	20	"	"
0600	30	10	"	10
0620	30	10	"	15
1640	30	10	"	10
0700	35	10	"	10
0720	35	10	"	15
0740	35	10	"	20
0800	40	10	"	25

DALMO VICTOR OZONE SENSOR
DATA REDUCTION

November 14, 1967

All Readings in PPB

TIME	D/V I.R.	D/V Mast	Regener	L.A. County
0800	30	10	4	25
0820	30	10	4	25
0840	25	10	4	30
0900	30	20	4.0	30
0920	35	20	4.0	40
0940	35	20	0	55
1000	40	20	9.0	50
1020	40	40	13.0	60
1040	25	60	9.0	60
1100	20	65	44	80
1120	30	110	160	120
1140	45	140	124	130
1200	50	170	252	200
1220	80	220	234	210
1240	100	330	245	280
1300	120	280	220	250
1320	135	230	225	180
1340	155	160	97	70
1400	150	70	25	50
1420	140	25	14	25
1440	100	25	18	25
1500	50	25	22	20
1520	40	30	40	35
1540	50	60	86	60
1600	50	110	47	60
1620	55	60	11	30
1640	55	45	7	10
1700	40	20	0	10
1720	30	20	0	10
1740	20	20	7	10
1800	10	15	7	10
1820	10	15	7	10
1840	10	15	7	10
1900	5	15	7	10
1920	15	15	7	10
1940	10	15	7	10
2000	10	10	7	10

Dalmo Victor Ozone Sensor Data Reduction
All Readings in PPB

November 14, 1967
Page Two

TIME	D/V I.R.	D/V Mast	Regener	L.A. County
2020	15	10	7	Blank Sampling
2040	10	10	7	"
2100	5	10	7	"
2120	5	10	No Data	"
2140	10	10	"	"
2200	5	10	"	"
2220	20	10	"	"
2240	25	10	"	"
2300	30	10	"	"
2320	20	10	"	"
2340	20	10	"	"
2400	25	10	"	"
2420	20	10	"	"
2440	20	10	"	"
0100	15	10	"	"
0120	15	10	"	"
0140	25	10	"	"
0200	25	10	"	"
0220	10	10	"	"
0240	10	10	"	"
0300	10	10	"	"
0320	10	10	"	"
0340	25	10	"	"
0400	35	10	"	"
0420	30	10	"	"
0440	50	10	"	"
0500	55	10	"	"
0520	55	10	"	"
0540	50	10	"	"
0600	50	10	"	"
0620	50	10	"	"
0640	50	10	"	"
0700	50	10	"	"
0720	50	10	"	"
0740	50	10	"	"
0800	50	10	"	"

DALMO VICTOR OZONE SENSOR

DATA REDUCTION

November 15, 1967

All Readings in PPB

TIME	D/V I.R.	D/V Mast	Regener	L.A. County
0800	50	10	No Data	10
0820	45	10	"	15
0840	50	20	"	25
0900	45	20	"	35
0920	45	20	"	50
0940	45	20	"	60
1000	45	35	"	65
1020	45	40	"	75
1040	55	55	"	80
1100	65	90	"	100
1120	90	100	127	150
1140	120	130	124	170
1200	135	170	172	190
1220	120	220	205	220
1240	105	200	168	220
1300	105	240	226	220
1320	110	180	182	120
1340	95	160	127	115
1400	85	140	134	115
1420	80	135	120	110
1440	45	110	79	107
1500	30	105	82	107
1520	20	80	103	107
1540	20	70	34	108
1600	45	110	127	130
1620	40	90	62	80
1640	20	50	14	70
1700	40	70	48	60
1720	20	70	45	75
1740	35	110	51	70
1800	30	80	48	70
1820	25	60	27	40
1840	15	40	7	30
1900	10	30	10	20
1920	20	30	10	20
1940	25	15	10	15
2000	25	15	10	15

D/V Ozone Sensor Data Reduction
All readings in PPB

November 15, 1967
Page Two

TIME	D/V I.R.	D/V Mast	Regener	L. A. County
2020	35	15	10	15
2040	35	15	10	10
2100	30	20	10	10
2120	30	15	10	10
2200	25	10	10	10
2220	25	10	10	10
2240	20	10	10	10
2300	20	10	10	10
2320	20	10	10	10
2340	15	10	10	10
2400	15	10	10	10
2420	15	10	10	10
2440	20	10	10	10
0100	20	10	10	10
0120	30	10	10	10
0140	30	10	10	10
0200	30	10	10	10
0220	30	10	10	10
0240	35	10	10	10
0300	35	10	10	10
0320	40	10	10	10
0340	45	10	10	10
0400	40	10	10	10
0420	35	10	10	10
0440	40	10	10	10
0500	40	20	10	10
0520	45	20	10	10
0540	50	20	10	10
0600	50	10	10	10
0620	50	10	10	10
0640	50	10	10	10
0700	65	10	10	10
0720	65	10	10	10
0740	70	10	10	10
0800	60	10	10	10

DALMO VICTOR OZONE SENSOR
DATA REDUCTION

November 16, 1967

	SYSTEM			
TIME	D/V I.R.	D/V Mast	Regener	L. A. County
0800	55	10	1.0	20
0820	45	10	1.0	20
0840	45	10	1.0	25
0900	40	25	4.0	30
0920	35	25	11.0	50
0940	30	35	7.0	50
1000	30	40	11.0	60
1020	35	55	19.0	70
1040	40	60	23.0	70
1100	55	70	64.0	80
1120	70	80	98.0	100
1140	80	140	177.0	115
1200	80	150	140	150
1220	50	120	83.0	85
1240	25	110	124	80
1300	25	110	140	90
1320	70	140	151	130
1340	70	170	170	135
1400	60	180	140	155
1420	70	140	117	100
1440	45	130	83	100
1500	70	150	151	150
1520	60	140	94	95
1540	40	90	23	60
1600	30	40	8	30
1620	10	30	2	20
1640	20	25	0	10
1700	5	25	0	10
1720	20	20	0	10
1740	20	20	0	10
1800	5	10	0	10
1820	0	10	0	10
1840	20	10	0	10
1900	25	10	0	10
1920	30	10	0	10
1940	5	10	0	10
2000	5	10	0	10
2020	10	10	0	10
2040	5	10	0	10
2100	10	10	0	10
2120	20	10	0	10
2140	15	10	0	10

Dalmo Victor Ozone Sensor
All readings in PPB

2200		15	10	0	10
2220		15	10	0	10
2240		15	10	0	10
2300		10	10	0	10
2320		10	10	0	10
2340		15	10	0	10
2400		10	10	0	10
2420	(11/17)	10	10	0	10
2440		20	10	0	10
0100		25	10	0	10
0120		35	10	0	10
0140		30	10	0	10
0200		30	10	0	10
0220		30	10	0	10
0240		30	10	0	10
0300		35	10	0	10
0320		35	10	0	10
0340		20	10	0	10
0400		20	10	0	10
0420		30	10	0	10
0440		20	10	0	10
0500		20	10	0	10
0520		20	10	0	10
0540		40	10	0	10
0600		60	10	0	10
0620		45	10	0	10
0640		25	10	0	10
0700		10	10	0	10
0720		20	10	0	10
0740		15	10	0	10
0800					

DALMO VICTOR OZONE SENSOR
DATA REDUCTION

November 17, 1967

	SYSTEM			
TIME	D/V I.R.	D/V Mast	Regener	L. A. County
0800	10	10	2.0	20
0820	20	10	2.0	20
0840	20	10	2.0	25
0900	20	10	2.0	30
0920	20	10	4	50
0940	25	10	4	50
1000	25	15	8	60
1020	15	20	8	70
1040	20	40	8	70
1100	10	50	34	100
1120	25	80	80	110
1140	40	100	109	140
1200	40	145	142	150
1220	45	150	105	80
1240	40	150	71	90
1300	60	160	117	90
1320	75	140	130	140
1340	70	110	113	140
1400	75	130	109	150
1420	70	150	105	100
1440	50	150	117	100
1500	25	110	53	100
1520	25	70	40	110
1540	15	60	53	70
1600	10	55	13	30
1620	5	40	4	20
1640	0	30	4	10
1700	0	25	4	10
1720	0	25	4	10
1740	5	15	4	10
1800	10	15	4	10
1820	20	15	4	10
1840	30	20	4	10
1900	30	20	4	10
1920	35	20	4	10
1940	40	15	4	10
2000	35	15	4	10
2020	35	15	4	10
2040	30	15	4	10
2100	20	20	4	10
2120	30	20	4	10
2140	25	20	4	10
2200	25	10	4	10
2220	25	10	4	10
2240	30	10	4	10

DV Ozone Sensor Data Reduction

November 17, 1967
Page Two

TIME	D/V I.R.	D/V Mast	Regener	L.A. County
2300	35	25	4	10
2320	25	25	4	10
2340	20	10	4	10
2400	10	10		
2420	15	10		
2440	10	10		
0100	15	25		
0120	25	25		
0140	55	10		
0200	55	10		
0220	55	10		
0240	50	10		
0300	50	20		
0320	45	20		
0340	1.5	15		
0400	50	15		
0420	45	15		
0440	40	15		
0500	35	20		
0520	35	20		
0540	35	20		
0600	35	10		
0620	35	10		
0640	35	10		
0700	35	20		
0720	35	20		
0740	35	10		
0800	35	10		

DALMO VICTOR OZONE SENSOR
DATA REDUCTION

November 18, 1967

TIME	D/V I.R.	D/V Mast	Regener	L. A. County
0800	35	10	5	10
0820	45	10	5	10
0840	20	30	5	10
0900	10	45	5	10
0920	0	45	19	10
0940	5	40	19	15
1000	15	30	38	20
1020	5	50	90	20
1040	10	70	80	50
1100	25	80	66	60
1120	20	90	108	110
1140	20	120	104	120
1200	20	130	91	150
1220	15	120	85	120
1240	20	80	60	130
1300	20	80	55	130
1320	5	60	35	130
1340	25	40	25	100
1400	20	40	25	130
1420	0	40	20	130
1440	Data Lost	40	30	130
1500	due to storm.	45	15	70
1520	"	35	30	60
1540	"	35	15	50
1600	"	35	20	40
1620	"	45	30	30
1640	"	40	10	20
1700	"	30	3	10
1720	"	30	3	10
1740	"	20	3	10
1800	"	20	3	10
1820	"	20	3	10
1840	"	20	3	10
1900	"	20	3	10
1920	"	20	3	10
1940	"	20	3	10
2000	"	15	3	10
2020	"	15	3	10
2040	"	15	3	10
2100	"	15	3	10
2120	"	15	3	10
2140	"	15	3	10

DV Ozone Sensor Data Reduction

November 18, 1967

TIME	D/V I.R.	D/V Mast	Regener	L. A. County
2200	0	15	3	10
2220	0	15	3	10
2240	0	15	3	10
2300	0	20	3	10
2320	0	20	3	10
2340	0	10	3	10
2400	0	10	3	10
2420	0	15	3	10
2440	0	15	3	10
0100	0	15	3	10
0120	0	15	3	10
0140	0	40	3	10
0200	0	110	3	10
0220	0	110	3	10
0240	0	150	3	10
0300	0	180	3	10
0320	0	190	3	10
0340	0	170	3	10
0400	0	160	3	10
0420	0	140	3	10
0440	0	100	3	10
0500	0	80	3	10
0520	0	75	3	10
0540	0	60	3	10
0600	0	60	3	10
0620	0	65	3	10
0640	0	65	3	10
0700	0	60	3	10
0720	0	60	3	10
0740	0	60	3	10
0800	0	55	10	10

DALMO VICTOR OZONE SENSOR
DATA REDUCTION

November 19, 1967

TIME	D/V I.R.	D/V Mast	Regener	L.A. County
1800	No data available	55	No data available	10
1820	"	55	"	10
1840	"	10	"	20
1900	"	70	"	30
1920	"	60	"	30
1940	"	60	"	35
2000	"	60	"	40
2020	"	70	"	50
2040	"	70	"	60
2100	"	80	"	80
2120	"	80	"	85
2140	"	60	"	90
2200	"	80	"	110
2220	"	70	"	90
2240	"	70	"	80
2300	"	70	"	50
2320	"	70	"	40
2340	"	50	"	20
2400	"	60	"	20
1420	"	55	"	20
1440	"	55	"	30
1500	"	50	"	30
1520	"	50	"	20
1540	"	40	"	20
1600	"	35	"	20
1620	"	35	"	20
1640	"	35	"	20
1700	"	35	"	20
1720	"	35	"	20
1740	"	35	"	20
1800	"	35	"	20
1820	"	35	"	20
1840	"	35	"	20
1900	"	35	"	20
1920	"	35	"	20
1940	"	25	"	20
2000	"	25	"	20
2020	"	25	"	20
2040	"	40	"	20
2100	"	40	"	10
2120	"	40	"	10
2140	"	30	"	10
2200	"	30	"	10
2220	"	30	"	10
2240	"	35	"	10
2300	"	35	"	10
2320	"	35	"	10
2340	"	25	"	10
2400	"	25	"	10

DV Ozone Sensor Data Reduction

November 19, 1967

TIME	D/V I.R.	D/V Mast	Regener	L.A. County
2420	No data	25	No data	10
2440	available	40	available	10
0100	"	40	"	10
0120	"	40	"	10
0140	"	35	"	10
0200	"	35	"	10
0220	"	50	"	10
0240	"	55	"	10
0300	"	55	"	10
0320	"	50	"	10
0340	"	35	"	10
0400	"	35	"	10
0420	"	35	"	10
0440	"	40	"	10
0500	"	40	"	10
0520	"	45	"	10
0540	"	25	"	10
0600	"	25	"	10
0620	"	25	"	10
0640	"	25	"	10
0700	"	25	"	10
0720	"	25	"	10
0740	"	25	"	10
0800	"	25	"	10

DALMO VICTOR OZONE SENSOR
DATA REDUCTION

November 20, 1967

TIME	D/V I.R.	D/V Mast	Regener	L.A. County
0800	No data	25	No data	0
0820	available	30	available	0
0840	"	35	"	10
0900	"	50	"	10
0920	"	50	"	10
0940	"	50	"	10
1000	"	50	"	10
1020	"	50	"	10
1040	"	40	"	10
1100	"	40	"	10
1120	"	40	"	10
1140	"	35	"	10
1200	"	35	"	10
1220	"	30	"	10
1240	"	30	"	10
1300	"	30	"	10
1320	"	30	"	10
1340	35	30	"	10
1400	40	30	"	10
1420	45	25	"	10
1440	45	25	"	10
1500	40	25	"	10
1520	40	30	"	10
1540	45	30	"	10
1600	40	30	"	10
1620	45	30	"	10
1640	50	30	"	10
1700	55	40	"	10
1720	55	40	"	10
1740	60	40	"	10
1800	65	30	"	10
1820	70	30	"	10
1840	60	30	"	10
1900	60	30	"	10
1920	60	30	"	10
1940	60	30	"	10
2000	50	30	"	10
2020	40	30	"	10
2040	50	30	"	10
2100	70	30	"	10
2120	65	30	"	10
2140	60	30	"	10
2200	50	30	"	10
2220	50	30	"	10
2240	65	30	"	10
2300	60	30	"	10
2320	65	30	"	10
2340	90	30	"	10
2400	75	30	"	10

Dalmo Victor Ozone Sensor Data Reduction

November 20, 1967

TIME	D/V I.R.	D/V Mast	Regener	L.A. County
2420	75	35	No data	10
2440	75	50	"	10
0100	80	50	"	10
0120	75	55	"	10
0140	80	55	"	10
0200	90	55	"	10
0220	85	50	"	10
0240	40	50	"	10
0300	40	50	"	10
0320	45	55	"	10
0340	45	45	"	10
0400	60	45	"	10
0420	60	45	"	10
0440	60	45	"	10
0500	55	45	"	10
0520	55	40	"	10
0540	50	30	"	10
0600	40	30	"	10
0620	40	30	"	10
0640	85	30	"	10
0700	75	40	"	10
0720	60	40	"	10
0740	60	30	"	10
0800	60	30	"	10

DALMO VICTOR OZONE SENSOR
DATA REDUCTION

November 21, 1967

TIME	D/V I.R.	D/V Mast	Regener	L.A. County
0800	60	30	No data	10
0820	55	30	available	10
0840	50	30	"	10
0900	60	30	"	10
0920	55	40	"	10
0940	60	40	"	10
1000	65	30	"	10
1020	80	30	"	10
1040	55	40	"	10
1100	55	40	"	10
1120	60	40	"	10
1140	55	30	"	10
1200	60	30	"	10
1220	50	40	"	10
1240	60	55	"	20
1300	60	60	"	20
1320	65	50	"	10
1340	55	35	"	10
1400	60	35	"	10
1420	75	40	"	10
1440	80	55	"	10
1500	80	55	"	10
1520	85	55	"	10
1540	80	40	"	10
1600	70	40	"	10
1620	60	40	"	10
1640	65	40	"	10
1700	70	40	"	10
1720	70	30	"	10
1740	55	30	"	10
1800	55	30	"	10
1820	60	30	"	10
1840	55	30	"	10
1900	55	30	"	10
1920	60	35	"	10
1940	60	30	"	10
2000	80	30	"	10
2020	65	30	"	10
2040	75	45	"	10
2100	Chopper	45	"	10
2120	Motor	40	"	10
2140	Failed	30	"	10
2200	"	30	"	10
2220	"	30	"	10
2240	"	30	"	10

DV Ozone Sensor Data Reduction

November 21, 1967
Page Two

TIME	D/V I.R.	D/V Mast	Regener	L.A. County
2300	Chopper Motor	35	No data	10
2320	Failed	35	"	10
2340	"	30	"	10
2400	"	30	"	10
2420	"	30	"	10
2440	"	30	"	10
0100	"	40	"	10
0120	"	40	"	10
0140	"	30	"	10
0200	"	30	"	10
0220	"	30	"	10
0240	"	30	"	10
0300	"	40	"	10
0320	"	30	"	10
0340	"	30	"	10
0400	"	30	"	10
0420	"	30	"	10
0440	"	30	"	10
0500	"	40	"	10
0520	"	40	"	10
0540	"	30	"	10
0600	"	30	"	10
0620	"	30	"	10
0640	"	40	"	10
0700	"	40	"	10
0720	"	40	"	10
0740	"	25	"	10
0800	"	25	"	10